(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 290 279 B1**

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication of patent specification: **21.07.93**

(51) Int. Cl.5: **A61B 5/00**, G01N 21/31

(21) Application number: **88304138.6**

(22) Date of filing: **06.05.88**

(54) Examination apparatus for measuring oxygenation.

(30) Priority: **08.05.87 JP 110471/87**

(43) Date of publication of application:
09.11.88 Bulletin 88/45

(45) Publication of the grant of the patent:
21.07.93 Bulletin 93/29

(84) Designated Contracting States:
DE GB

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EP 0 290 279 B1

Description

The present invention relates to the apparatus for measuring the oxygen concentration in objects such as organs, e.g. the cerebral tissues, of a human body or animals, especially relates to the apparatus for measuring the oxygenation of hemoglobin in blood and that of cytochrome in cells by detecting their effect on electromagnetic radiation.

In general, in diagnosing the function of the body organ, e.g. the cerebral tissues, it is a fundamental and important parameter whether the oxygen quantity in the body organ is sufficient and it is suitably used. Supplying body organs with sufficient quantity of oxygen is indispensable for the growth ability of foetuses and new-born infants. If the supply of oxygen is insufficient, the death rates of foetuses and new-born infants are high, and even if they live serious problems in body organs may remain as a consequence. The insufficiency of oxygen affects every body organ, especially causes a serious damage in the cerebral tissues.

To examine the oxygen quantity in body organs readily and at the early stage of illness, an examination apparatus disclosed in US-A-4,281,645 has been developed. In this kind of examination apparatus, the variation of oxygen quantity in body organs, especially in the brain is measured through the absorption spectrum of near infrared light in which the absorption is caused by the hemoglobin which is an oxygen-carrying medium in blood and the cytochrome a, a_3 which performs oxydation-reduction reaction in cells. As shown in Fig. 4(a), the absorption spectra of near infrared light (700 to 1300 nm), α_{HbO2} and α_{Hb} by oxygenated hemoglobin (HbO_2) and disoxygenated hemoglobin (Hb), respectively, are different from each other. And as shown in Fig. 4(b), the absorption spectra of that, α_{CyO2} and α_{Cy} by oxidized cytochrome a, a_3 (CyO_2) and reduced cytochrome a, a_3 (Cy), respectively, are different from each other. This examination apparatus utilizes the above-described absorption spectra of near infrared light. Four near infrared light rays with different wavelengths, λ_1, λ_2, λ_3 and λ_4 (e.g. 775 nm, 800 nm, 825 nm and 850 nm) are applied to one side of the patient's head with a time-sharing method and the transmission light rays from the opposite side of the head are in turn detected. By processing these four detected results with the prescribed calculation program, four unknown quantities, i.e. the density variations of oxygenated hemoglobin (HbO_2), disoxygenated hemoglobin (Hb), oxidized cytochrome a, a_3 (CyO_2) and reduced cytochrome a, a_3 (Cy) are calculated and being based on these parameters, for example the variation of a cerebral oxygen quantity is obtained.

Fig. 5 shows a system outline of the above-described conventional examination apparatus 45. The conventional examination apparatus 45 includes; light sources such as laser diodes LD1 to LD4 which emit four near infrared light rays with different wavelengths of λ_1, λ_2, λ_3 and λ_4, respectively; a light source control device 55 which controls output timing of the light sources LD1 to LD4; optical fibers 50-1 to 50-4 which introduces near infrared light rays emitted by the light sources LD1 to LD4 to a patient's head 40; an illumination-side fixture 51 which bundles and holds end portions of the optical fibers 50-1 to 50-4; a detection-side fixture 52 which is fitted to the prescribed position of the opposite side of the patient's head 40; a optical fiber 53 which is held by the detection-side fixture 52 and introduces transmitted near infrared light from the patient's head 40; a transmission light detection device 54 which measures transmission quantity of near infrared light by counting photons of near infrared light introduced by the optical fiber 53; and a computer system 56 which controls the total examination apparatus and determines the variation of oxygen quantity in cerebral tissues being based on the transmission quantity of near infrared light.

The computer system 56 is equipped with a processor 62, a memory 63, output devices 64 such as a display and a printer, and an input device 65 such as a keyboard, and these devices are connected each other by a system bus 66. The light source control device 55 and the transmission light detection device 54 are connected to the system bus 66 as external I/O's.

The light source control device 55 drives the light sources LD1 to LD4 by respective driving signals ACT1 to ACT4 as shown in Fig. 6(a) to 6(d) according to instructions from the computer system 56. As shown in Fig. 6 one measuring period M_k (k = 1, 2, ...) consists of N cycles of CY1 to CYn. At a phase Φn1 in an arbitrary cycle CYn, no light source of LD1 to LD4 is driven and therefore the patient's head 40 is not illuminated by the near infrared light from the light sources LD1 to LD4. At the phase Φn2 the light source LD1 is driven and the near infrared light with the wavelength of for example 775 nm is emitted from it. In the same manner, at the phase Φn3 the light source LD2 is driven and the near infrared light with the wavelength of for example 800 nm is emitted from it; at the phase Φn4 the light source LD3 is driven and the near infrared light with the wavelength of for example 825 nm is emitted from it; and at the phase Φn5 the light source LD4 is driven and the near infrared light with the wavelength of for example 850 nm is emitted from it. In this manner the light source control device 55 drives the light sources LD1 to LD4 sequentially with a time-sharing method.

The transmission light detection device 54 is equipped with a filter 57 which adjusts the quantity of near infrared light outputted from the optical fiber 53; lenses 70 and 71; a photomultiplier tube 58 which converts the light from the filter 57 into pulse current and outputs it; an amplifier 59 which amplifies the pulse current from the photomultiplier tube 58; an amplitude discriminator 60 which eliminates the pulse current from the amplifier 59 whose amplitude is smaller than the prescribed threshold value; a multi-channel photon-counter 61 which detects photon frequency in every channel; for example a detection controller 67 which controls detection periods of the multi-channel photon-counter 61; a temperature controller 68 which controls the temperature of a cooler 69 containing the photomultiplier tube 58.

In use of the above-described examination apparatus, the illumination-side fixture and the detection-side fixture are firmly fitted to the prescribed positions of the patient's head 40 by using a tape or the like. After that, the light sources LD1 to LD4 are driven by the light source control device 55 as shown in Fig. 6(a) to 6(d), respectively, so that the four near infrared light rays with different wavelengths are emitted from the light sources LD1 to LD4 sequentially with the time-sharing method, and the light rays are introduced by the optical fibers 50-1 to 50-4 to the patient's head 40. As bones and soft tissues in the patient's head 40 are transparent to the near infrared light, the near infrared light is partially absorbed mainly by hemoglobin in blood and cytochrome a, a_3 in cells and outputted to the optical fiber 53. And the optical fiber 53 introduces the light to the transmission light detection device 54. At the phase Φn1 no light source of LD1 to LD4 is driven, so that the transmission light detection device 54 does not receive the transmission light originally emitted from the light sources LD1 to LD4. At this phase the transmission light detection device 54 detects dark light.

The photomultiplier tube 58 in the transmission light detection device 54 is the one for photon-counting which has high sensitivity and operates at high response speed. The output pulse current from the photomultiplier tube 58 is sent to the amplitude discriminator 60 through the amplifier 59. The amplitude discriminator 60 eliminates the noise component whose amplitude is smaller than the prescribed amplitude threshold and sends only the signal pulse to the multi-channel photon-counter 61. The multi-channel photon-counter 61 detects photon number only in the periods T_0 which is made synchronized with the driving signals ACT1 to ACT4 for the respective light sources LD1 to LD4 as shown in Fig. 6(a) to (d) by a control signal CTL as shown in Fig. 6(e) from the detection controller 67, and counts detected photon number of every light with each wavelength sent from the optical fiber 53. The transmission data of every near infrared light with each wavelength are obtained through the above-described procedure.

That is, as shown in Fig. 6(a) to (e), at the phase Φn1 in the cycle CYn of light source control device 55 no light source of LD1 to LD4 is driven, therefore the dark light data d are counted by the transmission light detection device 54. At the phases Φn2 to Φn5 the light sources LD1 to LD4 are sequentially driven with the time-sharing method and the transmission light detection device 54 sequentially counts the transmission data $T_{\lambda1}$, $T_{\lambda2}$, $T_{\lambda3}$ and $T_{\lambda4}$ of the respective near infrared light rays with different wavelengths λ_1, λ_2, λ_3 and λ_4.

The counting of the dark light data d and the transmission data $t_{\lambda1}$, $t_{\lambda2}$, $t_{\lambda3}$ and $t_{\lambda4}$ which is sequentially performed in the cycle CYn, is continued N times from CY1 to CYn. That is, one measuring period M_k (k = 1, 2, ...) includes N cycles. A concrete example is as follows; if one cycle is 200 µsec and N is 10000, the measuring period M_k becomes 2 sec. At the time of finishing of one measuring period M_k, the counting result of the dark light data D

$$(= \sum_{n=1}^{N} d/CYn)$$

and the counting results of the transmission data $T_{\lambda1}$, $T_{\lambda2}$, $T_{\lambda3}$ and $T_{\lambda4}$

$$(= \sum_{n=1}^{N} t_{\lambda j} \ / \ CYn)$$

are transferred to the computer system 56 and stored in the memory 63.

The processor 62 performs the subtraction of the dark light component by using the combination of the transmission data and the dark data ($T_{\lambda1}$, $T_{\lambda2}$, $T_{\lambda3}$, $T_{\lambda4}$,

$$D)_{M_k}$$

being stored in the memory 63 after one measuring period M_k and the combination of those ($T_{\lambda 1}$, $T_{\lambda 2}$, $T_{\lambda 3}$, $T_{\lambda 4}$,

$$D)_{M_0}$$

at the start of measuring, and calculates the variation rates of the transmission light $\Delta T_{\lambda 1}$, $\Delta T_{\lambda 2}$, $\Delta T_{\lambda 3}$ and $\Delta T_{\lambda 4}$. That is, the variation rates of the transmission light $\Delta T_{\lambda 1}$, $\Delta T_{\lambda 2}$, $\Delta T_{\lambda 3}$ and $\Delta T_{\lambda 4}$ are calculated as:

$\Delta T_{\lambda j} = log[(T_{\lambda j}- D)_{Mk}/(T_{\lambda j}-D)_{Mo}]$ (j = 1 to 4). (1)

The use of logarithm in the above calculation of $\Delta T_{\lambda j}$ is to express the variation as an optical density.

Using the above-calculated variation rates of the transmission light $\Delta T_{\lambda 1}$, $\Delta T_{\lambda 2}$, $\Delta T_{\lambda 3}$ and $\Delta T_{\lambda 4}$, density variations of oxygenated hemoglobin (HbO_2), disoxygenated hemoglobin (Hb), oxidized cytochrome a, a_3 -(CyO_2) and reduced cytochrome a, a_3 which are expressed as

$$\Delta X_{HbO_2}$$

ΔX_{Hb},

$$\Delta X_{CyO_2}$$

and ΔX_{Cy}, respectively, can be determined. That is, each of density variations of

$$\Delta X_{HbO_2}$$

ΔX_{Hb},

$$\Delta X_{CyO_2}$$

and ΔX_{Cy} is calculated as:

$$\Delta X_i = \sum_{j=1}^{4} (\alpha_{ij})^{-1} \Delta T_{\lambda j} / \ell \quad \cdots\cdots\cdots\cdots (2)$$

where α_{ij} is an absorption coefficient of each component i (HbO_2, Hb, CyO_2, Cy) for each wavelength λ_j (λ_1, λ_2, λ_3, λ_4) and is predetermined from Fig. 4(a) and (b), and ℓ is the length of the patient's head 40 along the travelling direction of the near infrared light.

As the above-detected density variation components,

$$\Delta X_{HbO_2},$$

ΔX_{Hb},

$$\Delta X_{CyO_2}$$

and ΔX_{Cy}, reflect the variation of oxygen quantity in the brain, the variation of oxygen quantity in the brain can be known by outputting these detected results from the output device 64 and the diagnosis is made being based on these results.

It is required in the foregoing examination apparatus that the transmission efficiency through the paths between the light sources LD1 to LD4 and the transmission light detection device 54 is always kept constant. Especially, the transmission efficiency through the paths between the light sources LD1 to LD4 and the photomultiplier tube 58 should be always kept constant.

But the above transmission efficiency is likely to be changed by following causes. Generally, as this kind of examination apparatus is frequently moved from one bed to another bed and the fixtures 51, 52 are frequently put on and off, the fixtures 51, 52 are likely to be damaged or stained, or the optical system such as the lenses 70, 71 is likely to get out of position. As the measurement of oxygenation sometimes lasts for twenty-four hours, the light sources LD1 to LD4 and the photomultiplier tube 58 are likely to be deteriorated.

Therefore, the examination apparatus in which the inspection of the light sources LD1 to LD4, fixtures 51, 52 and the optical system such as lenses 70, 71 and the photomultiplier tube 58 in the transmission light detection device 54 can be done before the measurement, is required. Especially, as the optical system such as the lenses 70, 71 and the photomultiplier tube 58 in the transmission light detection device 54 are delicate, the characteristics of those are likely to be changed. Therefore, the examination apparatus in which the inspection of those can be separately made, is also required.

Moreover, as the oxygenation measurement is continuously performed for a long time as described above, it happens during the measurement that the optical system gets out of position, the window of the photomultiplier tube 58 is clouded up by the cooling operation of the cooler 69, or the photomultiplier tube 58 deteriorates. Accordingly, it would be desirable to provide an examination apparatus in which the optical system, the transmitted light detection device and the photomultiplier tube 58 can be inspected.

According to a first aspect of this invention an examination apparatus for measuring the oxygenation of an object by electromagnetic radiation transmission spectrophotometry, comprising:

a light source means for sequentially emitting electromagnetic radiation at a number of different wavelengths;

an illumination-side fixture for applying the electromagnetic radiation emitted by the light source means to an object;

a transmitted light detection means for detecting light transmitted through the object and outputting transmission light data;

a detection-side fixture for receiving electromagnetic radiation transmitted through the object and coupling the transmitted electromagnetic radiation to the transmitted light detection means; and,

a computer system for controlling the operation of the apparatus, receiving the first transmission light data, and calculating the oxygenation of the object;

is characterised in that the apparatus also includes:

an inspection light source means for outputting inspection electromagnetic radiation in accordance with instructions from the computer system;

in that the transmitted light detection means detects the inspection electromagnetic radiation emitted by the inspection light source means and outputs second path-transmission light data corresponding to a path within the transmission light detection means; and,

in that the computer system receives the second path-transmission light data from the transmitted light detection means and determines whether the transmitted light detection means is in a normal condition, on the basis of both the second path transmission light data and the output data of the inspection light source.

A particular embodiment of examination apparatus in accordance with this invention will now be descriged with reference to the accompanying drawings; in which:-

Figure 1 is a block diagram of an examination appratus according to an embodiment of the present invention;

Figure 2 is a section through an assembly of an illumination-side fixture and a detection-side fixture according to an embodiment of the invention;

Figure 3 is a section through another assembly of an illumination-side fixture and a detection-side fixture according to an embodiment of the invention;

Figures 4(a) and (b) are graphs showing absorption spectra of hemoglobin and cytochrome, respectively;

Figure 5 is a block diagram of a conventional examination apparatus; and,

Figures 6(a) to (e) are timing-charts of driving signals ACT1 to ACT4 and a control signal CTL, respectively.

Figure 1 is a block diagram showing an examination apparatus according to an embodiment of the invention. In Figure 1, blocks, parts and signals which are common to those in Figure 5 are designated by

the same reference numerals or characters as those in Figure 5. In the examination apparatus 1, optical fibres 50-1 to 50-4 are held by an illumination-side fixture 22 and an optical fibre 53 is held by a detection-side fixture 3 in the same manner as in the conventional examination apparatus 45. The illumination-side fixture 2 and the detection-side fixture 3 have respective flanges in peripheries of their surfaces coming into contact with each other. The illumination-side fixture 2 and detection-side fixture 3 are fitted to for example a head 40 of an object person as shown in Figure 1 in the oxygenation measurement. On the other hand, when the examination apparatus 1 is stored or had the custody of, or is inspected before the measurement, the fixtures 2 and 3 are made opposed and in close contact with each other by fitting a clasper 6 into the flanges 4 and 5 as shown in Fig. 2.

Fig. 3 shows another embodiment of the fixtures. the illumination-side fixture 2' and the detection-side fixture 3' in Fig. 3 are equipped with respective optical members such as prisms 7 and 8 inside those, so that a light path is changed by a prescribed angle, for example 90 degrees. By connecting the optical fibers 50-1 to 50-4 and 53 to respective prescribed surfaces of the prisms 7 and 8, the optical fibers 50-1 to 50-4 and 53 are kept in a natural state without being forced to bend when the fixtures 2' and 3' are fitted to each other. Instead of fitting the fixtures to each other by an external member such as the clasper 6 as in Figs. 2 and 3, means for fitting the fixtures may be included in the fixtures themselves.

The examination apparatus 1 shown in Fig. 1 is equipped with an output light detection device 10. The output light detection device 10 comprises an output light monitor 11 consisting of for example a photodiode, and a multi-channel data accumulator 12 which A/D-converters an analog electric signal from the output light monitor 11, accumulates A/D-converted output light quantity and outputs accumulated date as output light quantity data.

A selector 13 is connected to the output light detection device 10. Optical fibers 14-1 to 14-4 which introduce respective near infrared light rays emitted from the light sources LD1 to LD4, and an optical fiber 16 which introduces inspection light emitted from an inspection light source 15, are connected to the selector 13. The selector 13 selects light which should be sent to the output light detection device 10 out of the near infrared light rays from the optical fibers 14-1 to 14-4 and the inspection light from the optical fiber 16 according to a selection signal SEL sent from a computer system 20.

The inspection light source 15 is used to inspect the light transmission path within the transmission light detection device 54 before or during the measurement and is driven by an inspection light source driving device 17 under the control of the computer system 20. Output light rays emitted from the inspection light source 15 are sent to the selector 13 through the optical fiber 16, and to the transmission light detection device 54 through the optical fiber 18 so as to inspect if the optical system such as lenses 70 and 71 is kept in its normal position, if the window of the photomultiplier tube 58 is kept clear, and if the photomultiplier tube 58 has not been deteriorated.

In the computer system 20, a processor 21, a memory 22, an output device 23 and an input device 24 are connected to a system bus 25 in the same manner as in the conventional computer system 56. Furthermore, the computer system 20 has a function to inspect the examination apparatus 1 before and during the measurement.

The operation of the examination apparatus 1 with the foregoing constitution will be described in the following. First, to inspect the examination apparatus 1 before the oxygenation measurement, the illumination-side fixture 2 and the detection-side fixture 3 are made in close contact with each other as shown in Fig. 2. The computer system 20 gives instruction to the light source control device 55 so that near infrared light rays with different wavelengths $\lambda 1$ to $\lambda 4$ are sequentially emitted from the respective light sources LD1 to LD4. The near infrared light rays from the light sources LD1 to LD4 are introduced by the respectivew optical fibers 50-1 to 50-4 to the illumination-side fixture 2, directly made incident on the detection-side fixture 3 from the illumination-side fixture 2, and sent to the transmission light detection device 54 through the optical fiber 53. In the transmission light detection device 54, the near infrared light rays with different wavelengths $\lambda 1$ to $\lambda 4$ are sent to the photomultiplier tube 58 through a filter 57 and the lenses 70 and 71, path-transmission light quantities are counted by a multi-channel photon-counter 61 at every wavelength, and counted results (prescribed times, for example N times of counting) are sent to the computer system 20. The counted results are stored in the memory 22 of the computer system 20 as path transmission light data $TR_{\lambda 1}$, $TR_{\lambda 2}$, $TR_{\lambda 3}$ and $TR_{\lambda 4}$

The near infrared light rays emitted from the light sources LD1 to LD4 are also sent to the selector 13 through the respective optical fibers 14-1 to 14-4 as well as sent to the optical fibers 50-1 to 50-4. The selector 13 selects the near infrared light rays introduced from the optical fibers 14-1 to 14-4 according to the selection signal SEL sent from the computer system 20 and sends the selected near infrared light rays to the output light detection device 10. The output light detection device 10 accumulates at every wavelength output quantities of the near infrared light rays with different wavelengths $\lambda 1$ to $\lambda 4$ sequentially

sent from the respective light sources LD1 to LD4 and sends accumulation results to the computer system 20 after the accumulation of prescribed times, for example N times. The accumulation results are stored in the memory 22 of the computer system 20 as the output light data $I_{\lambda1}$, $I_{\lambda2}$, $I_{\lambda3}$ and $I_{\lambda4}$. In the memory 22 of the computer system 20 there stored in advance are output light data $I_{\lambda10}$, $I_{\lambda20}$, $I_{\lambda30}$ and $I_{\lambda40}$ which correspond to respective optimum light output powers of the light sources LD1 to LD4, and path-transmission light data $TR_{\lambda10}$, $TR_{\lambda20}$, $TR_{\lambda30}$ and $TR_{\lambda40}$ which should be obtained when the photomultiplier tube 58 is in an optimum condition.

The processor 21 compares the path-transmission light data $TR_{\lambda1}$ to $TR_{\lambda4}$ and the output light data $I_{\lambda1}$ to $I_{\lambda4}$ stored in the memory 22 with the respective optimum path-transmission light data $TR_{\lambda10}$ to $TR_{\lambda40}$ and the respective optimum output light data $I_{\lambda10}$ to $I_{\lambda40}$ also sored in the memory 22 so as to check if the path-transmission light data and the output light data are optimum. The results of the comparison are outputted to the output device 23 such as a printer or a display.

If one of the output light data $I_{\lambda1}$ to $I_{\lambda4}$ is much different from the corresponding one of the optimum output light data $I_{\lambda10}$ to $I_{\lambda40}$, it can be decided that the corresponding one of the light sources LD1 to LD4 has been deterioated or is not adjusted to the optimum condition.

If one of the path-transmission light data $TR_{\lambda1}$ to $TR_{\lambda4}$ is much different from the corresponding one of the optimum path-transmission light data $TR_{\lambda10}$ to $TR_{\lambda40}$ while the output light data $I_{\lambda1}$ to $I_{\lambda4}$ have normal values, it can be decided that the illumination-side fixture 2 or detection-side fixture 3 has been damaged or stained, the optical system such as the lenses 70, 71 has gotten out of position or the photomultiplier tube 58 has been deateriorated or the window of that has been clouded up. When only the optical system such as the lenses 70 and 71 and the photomultiplier tube 58 which are most delicate and whose characteirstics are likely to be changed, are inspecated, the inspection light emitted from the inspection light source 15 is directly introduced to the transmission light detection device 54. In this case the selector 13 selects the light from the inspection light source 15 according to the selection signal SEL. In this manner, the optical system and the photomultiplier tube 58 can be inspected more surely by directly sending the inspection light emitted from the inspection light source 15 to the transmission light detection device 54 and obtaining the path-transmission light data TS.

Besides the inspection before the measurement as described above, the inspection can be performed also in the midst of the measurement of the oxygenation as described in the following. In the measurement the ilumination-side fixture 2 and the detection-side fixture 3 are fitted to for example the head 40 as shown in Fig. 1. As described in the foregoing, the light sources LD1 to LD4 are sequentially driven so as to emit the near infrared light rays and the near infrared light rays are made incident on the head 40 through the respective optical fibers 50-1 to 50-4 and the illumination-side fixture 2. Then, the near infrared light rays transmitted from the head 40 are sent to the transmission light detection device 54 through the deatection-side fixture 3 and the optical fiber 53, the transmission quantities are counted in the transmission light detection device 54, and the counted results counted over one measuring period M_k are sent to the computer system 20. The oxygenation measurement is performed with one measuring period M_k ($k = 1, 2, ...$) as a measuring unit. In the examination apparatus shown in Fig. 1, inspection period is inserted after repeating the measuring period M_k prescribed times, for example m times ($k = 1$ to m). In the inspection period, the computer system 20 sends the selection signal SEL to the selector 13 so that the selector 13 provides the output light detection device 10 with the light emitted from the inspection light source 15. The computer system also controls the inspection light source driving device 17 so as to drive the inspection light source 15. The inspection light emitted from the inspection light source 15 is introduced to the transmission light detection device 54 by the optical fiber 18 and sent to the photomultiplier tube 58 through the optical system such as the filter 57 and the lenses 70 and 71. The path-transmission light data TS are obtained in the multi-channel photon-counter 61 and stored in the memory 22 of the computer system 20 at the end of the inspection period.

On the other hand, the light emitted from the inspection light source 15 is also introduced to the output light detection device 10 by the optical fiber 16. The output light data IS are obtained through the accumulation in the output light detection device 10 and stored in the memory 22 of the computer system 20 at the end of the inspection period.

The processor 21 confirms that the output power of the inspection light source 15 is appropriate being based on the output light data IS. Then, the processor 21 judges if the path-transmission light data TS are proper. The result of judgement is outputted from the output device 23. If the above-detected path-transmission light data TS are different from the previously determined optimum path-transmission data, it is decided that the optical system such as the lenses 70 and 71 or the photomultiplier tube 58 is not in the normal condition.

As the inspection period is inserted after the prescribed times (e.g. m times) of the measurement, the examination apparatus 1 can be regularly inspected in the midst of the long-time measurement without stopping the operation.

As described in the foregoing embodiments, before the oxygenation measurement the examination apparatus 1 is automatically inspected with the illumination-side fixture 2 and detection-side fixture 3 assembled together in the same manner as when they are stored or had the custody of, and the inspection result is outputted from the output device 23. Therefore, the inspection of the examination apparatus 1 can be done quickly and accurately without complicated operation. In the midst of the measurement, the inspection is regularly performed by inserting the inspection period after the prescribed times of the oxygenation measurement and the inspection results are outputted from the output device 23. Therefore, the inspection can be done quickly and accurately without stopping the measurement and the operator can know the condition of the examination apparatus 1 being based on the inspection results outputted from the output device 23.

Though the plural light sources are employed in the foregoing embodiments, the electromagnetic waves with different wavelengths may be obtained by using one white light source and filtering the white light emitted from the white light source. Moreover, the application of the examination apparatus of the invention is not limited to a medical field, but covers many fields including mere measurements. The measuring object is not limited to body organs but may be general objects such as a piece of flesh. Furthermore, the electromagnetic wave emitted from the light source is not limited to near infrared light but may be far infrared light, visible light or microwave, etc.

Claims

1. An examination apparatus (1) for measuring the oxygenation of an object by electromagnetic radiation transmission spectrophotometry, comprising:

   a light source means (LD1-LD4) for sequentially emitting electromagnetic radiation at a number of different wavelengths;

   an illumination-side fixture (2) for applying the electromagnetic radiation emitted by the light source means (LD1-LD4) to an object (40);

   a transmitted light detection means (54) for detecting light transmitted through the object (40) and outputting transmission light data;

   a detection-side fixture (3) for receiving electromagnetic radiation transmitted through the object (40) and coupling the transmitted electromagnetic radiation to the transmitted light detection means (54); and,

   a computer system (20) for controlling the operation of the apparatus, receiving the first transmission light data, and calculating the oxygenation of the object;

   characterised in that the apparatus also includes:

   an inspection light source means (15) for outputting inspection electromagnetic radiation in accordance with instructions from the computer system (20);

   in that the transmitted light detection means 854) detects the inspection electromagnetic radiation emitted by the inspection light source means (15) and outputs second path-transmission light data corresponding to a path within the transmission light detection means (53); and,

   in that the computer system (20) receives the second path-transmission light data from the transmitted light detection means (54) and determines whether the transmitted light detection means (54) is in a normal condition, on the basis of both the second path transmission light data and the output data of the inspection light source means (15).

2. An examination apparatus as claimed in claim 1, wherein the inspection electromagnetic radiation is emitted from the inspection light source means (15) in a period when the electromagnetic radiation is not emitted from the light source means (LD1-LD4) during the oxygenation measurement.

3. An examination apparatus as claimed in claim 1 or 2, further comprising:

   output light detection means (10) for detecting the electromagnetic radiation emitted by the light source means (LD1-LD4) or the inspection light source means (15) and outputting output light data; and,

   the computer system (20) further receives the output light data and further determines whether the light source means (LD1-LD4) or the inspection light source means (15) is in a normal condition.

4. An examination apparatus as claimed in claim 3, further comprising:
a selector (13) for receiving the electromagnetic radiation from the light source means (LD1-LD4) and the inspection light source means (15), selecting the electromagnetic radiation to be sent to the output light detection means (10) in accordance with an instruction from the computer system (20), and sending the selected electromagnetic radiation to the output light detection means (10).

5. An examination apparatus as claimed in any one of the preceding claims, wherein the illumination-side fixture (2) and the detection-side fixture (3) have structures (4, 5, 6) to enable them to be assembled together so that electromagnetic radiation output from the illumination-side fixture (2) is directly incident on and is received by the detection-side fixture (3).

6. An examination apparatus as claimed in any one of the preceding claims, wherein the electromagnetic radiation is near infrared light radiation.

Patentansprüche

1. Untersuchungs-Vorrichtung (1) zum Messen der Sauerstoffsättigung eines Objekts durch Elektromagnetstrahlungs-Durchlaßspektrophotometrie, welche umfaßt:
Lichtquellenmittel (LD1-LD4) zum sequentiellen Emittieren von elektromagnetischer Strahlung mit einer Anzahl von unterschiedlichen Wellenlängen;
eine beleuchtungsseitige Befestigung (2) zum Aufbringen der durch die Lichtquellenmittel (LD1-LD4) emittierten elektromagnetischen Strahlung auf ein Objekt (40);
ein Durchlaßlicht-Erfassungsmittel (54) zum Erfassen von durch das Objekt (40) durchgelassenem Licht und zum Ausgeben von Durchlaßlichtdaten;
eine erfassungsseitige Befestigung (3) zum Empfangen durch das Objekt (40) durchgelassener elektromagnetischer Strahlung und zum Koppeln der durchgelassenen elektromagnetischen Strahlung zu dem Durchlaßlicht-Erfassungsmittel (54); und
ein Computersystem (20) zum Steuern des Betriebs der Vorrichtung, zum Aufnehmen der ersten Durchlaßlichtdaten und zum Errechnen der Sauerstoffsättigung des Objekts;
dadurch gekennzeichnet, daß die Vorrichtung auch enthält:
ein Prüflichtquellenmittel (15) zum Ausgeben von elektromagnetischer Prüfstrahlung entsprechend Instruktionen von dem Computersystem (20);
wobei das Durchlaßlicht-Erfassungsmittel (54) die durch das Prüflichtquellenmittel (15) emittierte elektromagnetische Prüfstrahlung erfaßt und zweite Weg-Durchlaßlichtdaten ausgibt entsprechend einem Weg innerhalb des Durchlaßlicht-Erfassungsmittels (53); und
daß das Computersystem (20) die zweiten Durchlaßlichtdaten von dem Durchlaßlicht-Erfassungsmittel (54) erhält und aufgrund sowohl der zweiten Weg-Durchlaßlichtdaten wie auch der Ausgabedaten des Prüflichtquellenmittels (15) bestimmt, ob das Durchlaßlicht-Erfassungsmittel (54) sich in einem Normalzustand befindet.

2. Untersuchungs-Vorrichtung nach Anspruch 1, bei der die elektromagnetische Prüfstrahlung von dem Prüflichtquellenmittel (15) während eines Zeitraums emittiert wird, in dem während der Sauerstoffsättigungs-Messung die elektromagnetische Strahlung vom Lichtquellenmittel (LD1-LD4) nicht emittiert wird.

3. Untersuchungs-Vorrichtung nach Anspruch 1 oder 2, welche weiter umfaßt:
Ausgangslicht-Erfassungsmittel (10) zum Erfassen der durch das Lichtquellenmittel (LD1-LD4) oder das Prüflichtquellenmittel (15) emittierten elektromagnetischen Strahlung und zum Ausgeben von Ausgabe-Lichtdaten; und
bei dem das Computersystem (20) weiter die Ausgabe-Lichtdaten erhält und weiter bestimmt, ob sich das Lichtquellenmittel (LD1-LD4) oder das Prüflichtquellenmittel (15) in einem normalen Zustand befindet.

4. Untersuchungs-Vorrichtung nach Anspruch 3, welche weiter umfaßt:
ein Auswählgerät (13) zum Empfangen der elektromagnetischen Strahlung vom Lichtquellenmittel (LD1-LD4) und dem Prüflichtquellenmittel (15), zum Auswählen der zu dem Ausgangslicht-Erfassungsmittel (10) zu sendenden elektromagnetischen Strahlung entsprechend einer Instruktion vom Computersystem (20) und zum Senden der ausgewählten elektromagnetischen Strahlung zu dem Ausgangslicht-Erfas-

sungsmittel (10).

5. Untersuchungs-Vorrichtung nach einem der vorangehenden Ansprüche, bei der die beleuchtungsseitige Befestigung (2) und die erfassungsseitige Befestigung (3) Strukturen (4, 5, 6) besitzen, die es ermöglichen, sie so zusammenzufügen, daß von der beleuchtungsseitigen Befestigung (2) ausgegebene elektromagnetische Strahlung direkt auf die erfassungsseitige Befestigung (3) auffällt und von ihr aufgenommen wird.

6. Untersuchungs-Vorrichtung nach einem der vorangehenden Ansprüche, bei der die elektromagnetische Strahlung Lichtstrahlung in nahen Infrarotbereich ist.

Revendications

1. Appareil de contrôle (1) pour mesurer l'oxygénation d'un objet par spectrophotométrie électromagnétique de transmission de rayonnement, comportant:
   des moyens à source de lumière (LD1-LD4, 38) pour émettre en séquence le rayonnement électromagnétique de plusieurs longueurs d'onde différentes;
   un dispositif du côté illumination (32) pour appliquer le rayonnement électromagnétique émis par les moyens de source de lumière (LD1-LD4) à un objet (40);
   des moyens capteurs de lumière transmise (54) pour capter le rayonnement électromagnétique transmis au travers de l'objet (40) et pour en sortir des données de lumière transmise;
   un dispositif du côté capteur (3) pour recevoir le rayonnement électromagnétique transmis au travers de l'objet (40) et pour accoupler le rayonnement électromagnétique aux moyens capteurs de lumière transmise (54); et,
   un système ordinateur (20) pour commander les fonctions de l'appareil, recevant les premières données de lumière transmise, et calculant l'oxygénation de l'objet;
   caractérisé en ce que le dispositif comporte aussi:
   des moyens à source de lumière de contrôle (15) pour sortir le rayonnement électromagnétique selon les consignes du système ordinateur (20);
   et en ce que les moyens capteurs de lumière transmise (54) captent le rayonnement électromagnétique émis par les moyens à source de lumière de contrôle (15) et sortent les données de lumière de deuxième parcours de transmission correspondant à un parcours dans les moyens capteurs de lumière transmise (53); et,
   en ce que le système ordinateur reçoit les données de lumière de deuxième parcours de transmission depuis les moyens de lumière transmise (54) et détermine si les moyens capteurs de lumière transmise sont en mode normal, selon à la fois les données de transmission de deuxième parcours et les données de sortie des moyens de contrôle à source de lumière (15).

2. Appareil de contrôle selon la revendication 1, dont le rayonnement électromagnétique de contrôle est émis par les moyens de contrôle à source de lumière (15) dans un délai pendant lequel le rayonnement électromagnétique n'est pas émis depuis les moyens à source de lumière (LD1-LD4) lors de la mesure d'oxygénation.

3. Appareil de contrôle tel qu'à la revendication 1 ou la revendication 2, comportant en outre:
   des moyens capteurs de sortie de lumière (10) pour capter le rayonnement électromagnétique émis par les moyens source de lumière (LD1-LD4) ou les moyens à source de lumière de contrôle (15) et sortant les données de sortie de lumière de sortie; et,
   le système ordinateur (20) reçoit en outre les données de sortie de lumière et détermine aussi si les moyens source de lumière (LD1-LD4) ou les moyens à source de lumière de contrôle (15) sont en mode normal.

4. Appareil de contrôle tel qu'à la revendication 3, comportant en outre:
   un sélecteur (13) pour recevoir le rayonnement électromagnétique des moyens à source de lumière (LD1-LD4) et des moyens à source de lumière de contrôle (15), sélectionnant le rayonnement électromagnétique à envoyer aux moyens capteurs de lumière de sortie (10) selon une consigne du système ordinateur (20), et envoyant le rayonnement électromagnétique aux moyens capteurs de lumière de sortie (10).

5. Appareil de contrôle tel qu'à l'une ou l'autre des revendications précédentes, dont le dispositif de côté illumination (2) et le dispositif de côté capteur (3) ont des structures (4, 5, 6) leur permettant d'être montées ensemble de telle façon que la sortie de rayonnement électromagnétique du dispositif de côté illumination (2) tombe incident directement sur le dispositif de côté capteur (3) qui le reçoit.

6. Appareil de contrôle tel qu'à l'une ou l'autre des revendications précédentes, dont le rayonnement électromagnétique est proche du rayonnement de lumière infra-rouge.

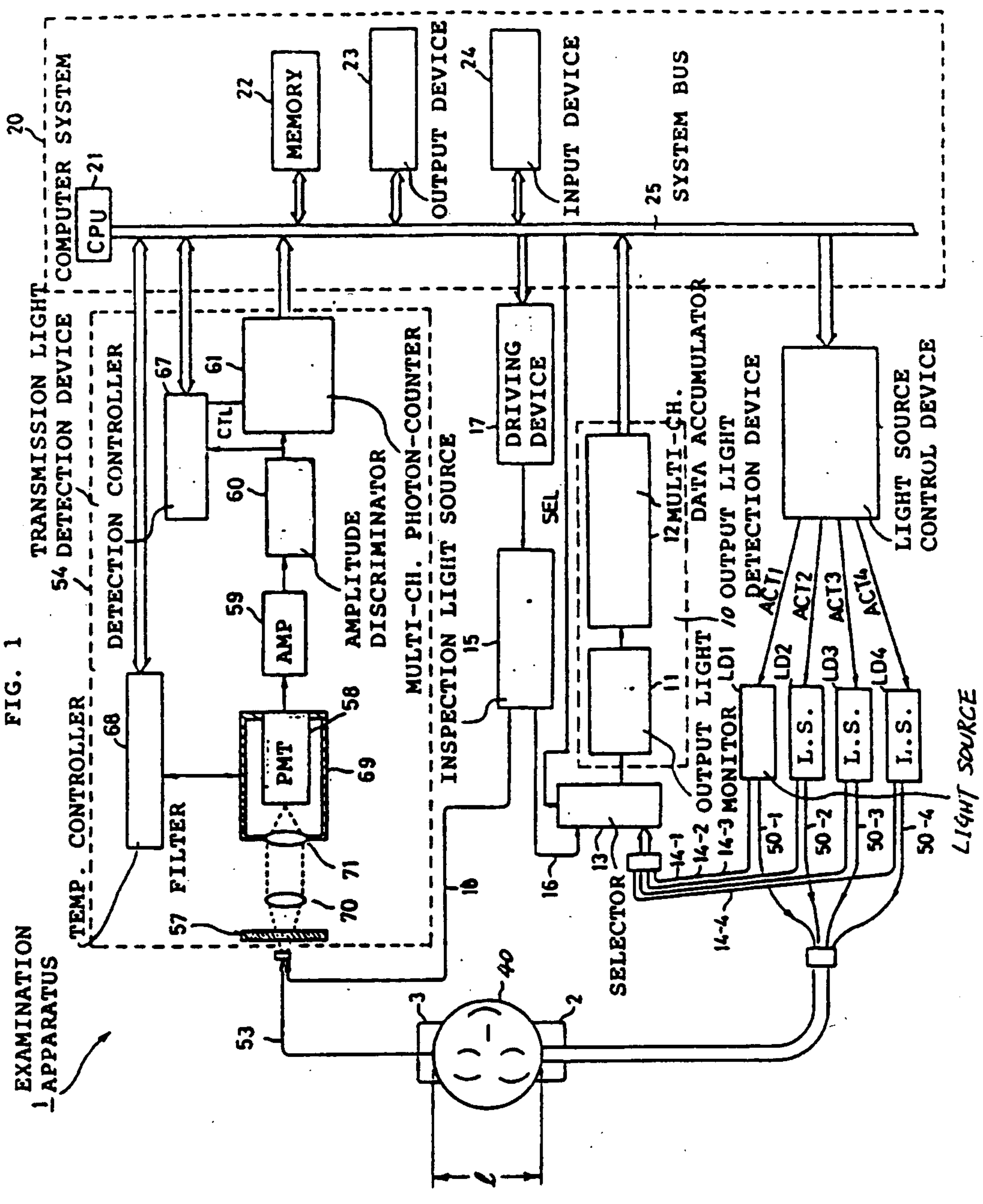

EXAMINATION APPARATUS
TEMP. CONTROLLER
DETECTION CONTROLLER
TRANSMISSION LIGHT DETECTION DEVICE
COMPUTER SYSTEM
CPU
MEMORY
OUTPUT DEVICE
INPUT DEVICE
SYSTEM BUS
FILTER
PMT
AMP
CTL
AMPLITUDE DISCRIMINATOR
MULTI-CH. PHOTON-COUNTER
INSPECTION LIGHT SOURCE
DRIVING DEVICE
SEL
MULTI-CH. DATA ACCUMULATOR
OUTPUT LIGHT DETECTION DEVICE
OUTPUT LIGHT MONITOR
SELECTOR
LIGHT SOURCE CONTROL DEVICE
ACT1
ACT2
ACT3
ACT4
LD1
LD2
LD3
LD4
L.S.
LIGHT SOURCE

FIG. 1

FIG. 2

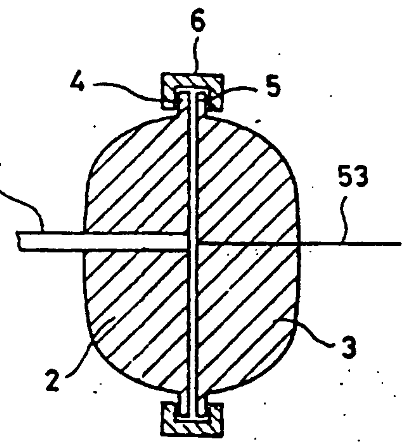


FIG. 3

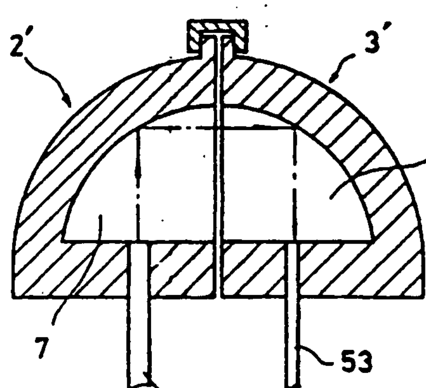


FIG. 4 (a)

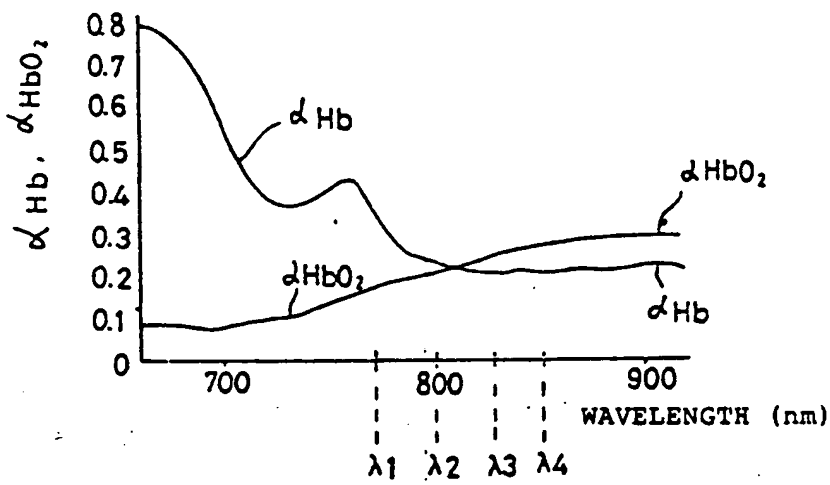

0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
α Hb, α HbO_2
α Hb
α HbO_2
α HbO_2
α Hb
700
800
900
WAVELENGTH (nm)
λ1
λ2
λ3
λ4

FIG. 4 (b)

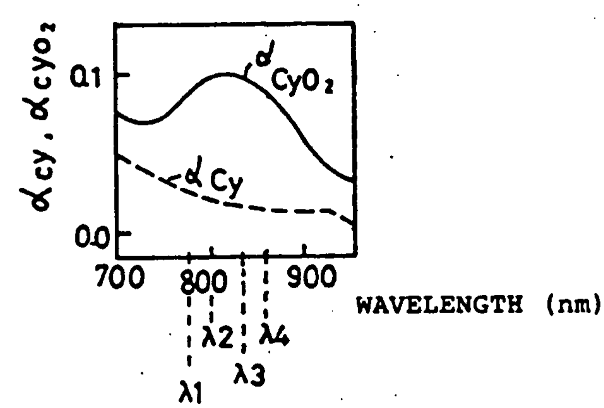

α cy, α cyo_2
0.1
0.0
α CyO_2
α Cy
700
800
900
WAVELENGTH (nm)
λ1
λ2
λ3
λ4

FIG. 5

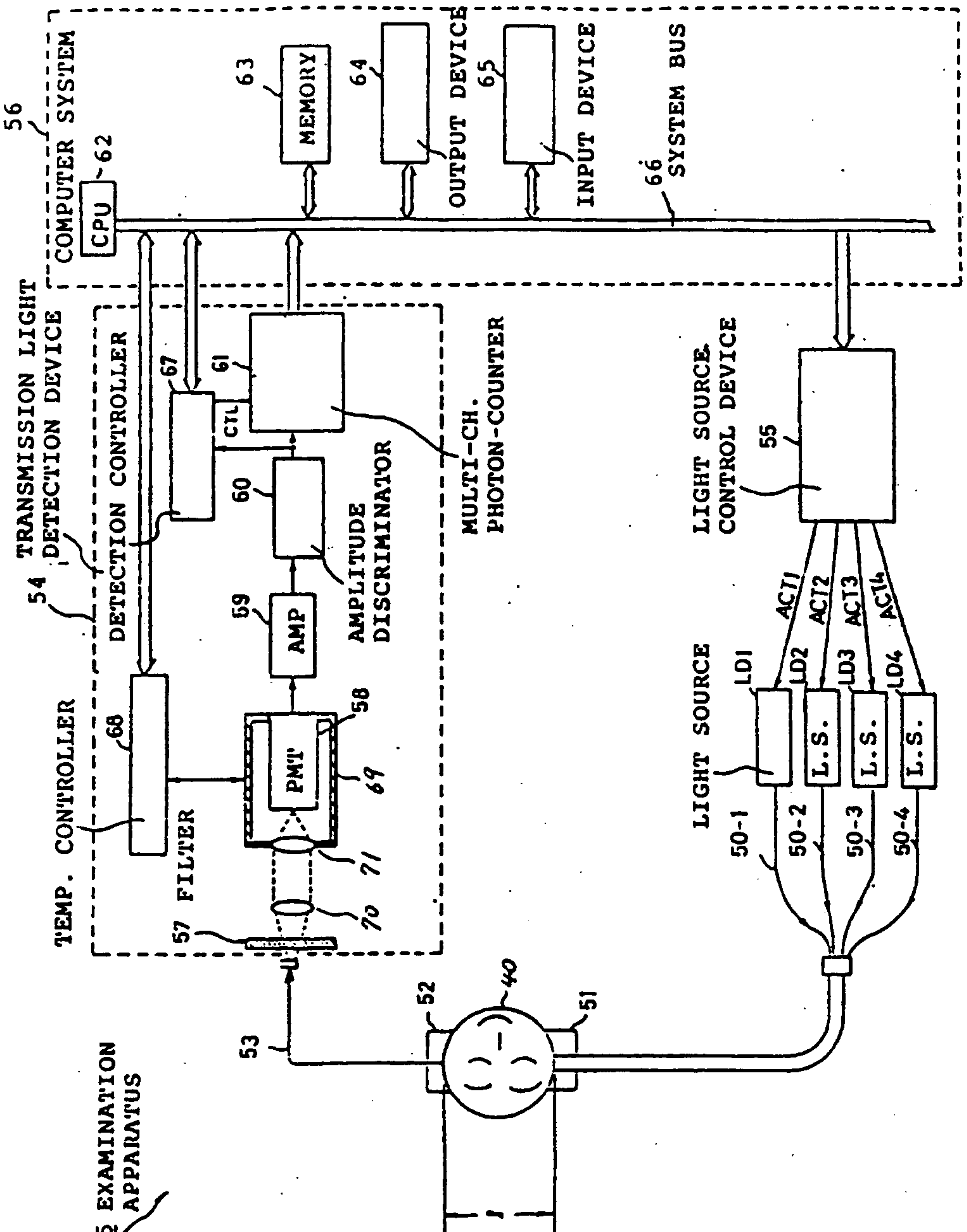
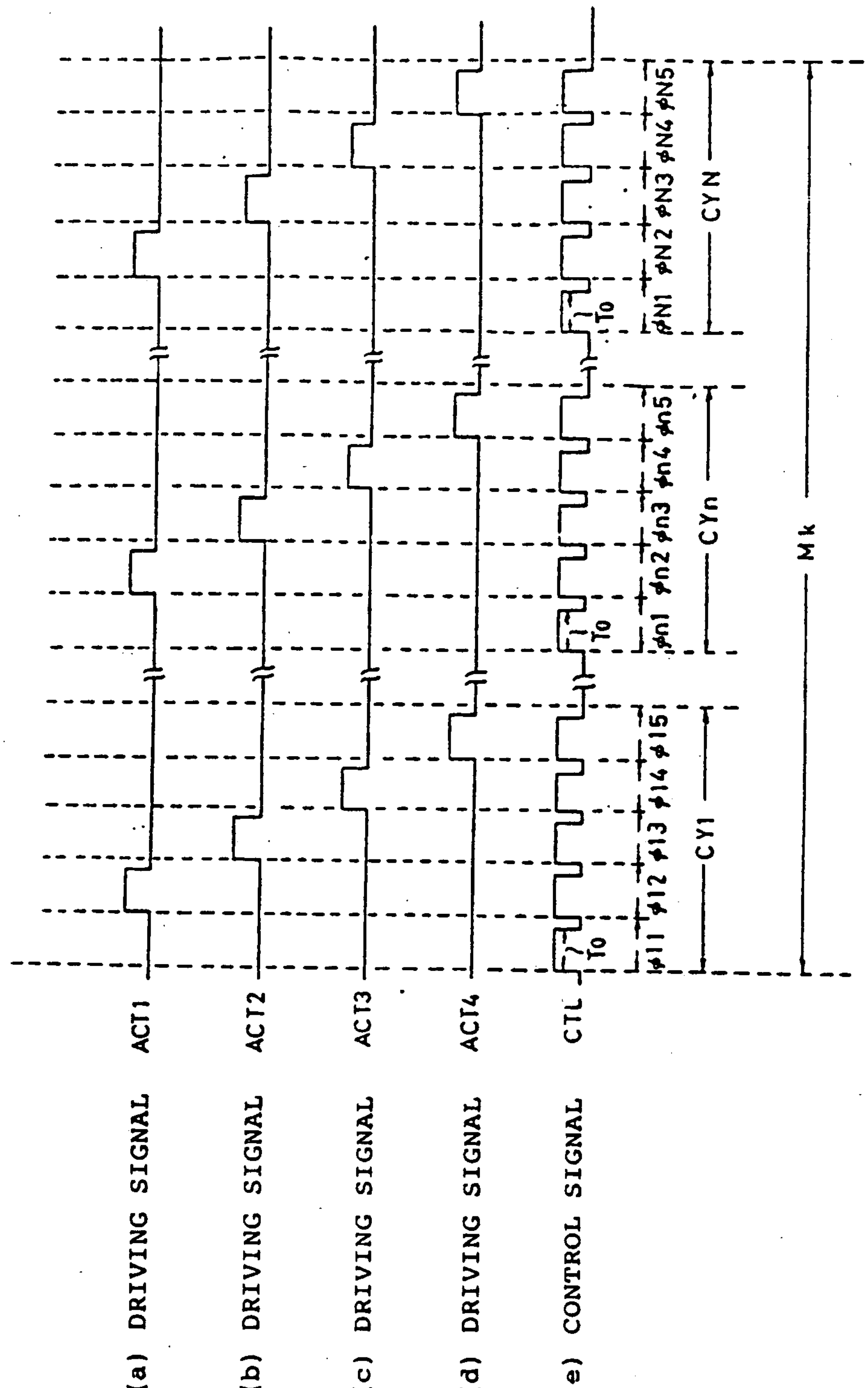

56
COMPUTER SYSTEM
CPU
62
63
MEMORY
64
OUTPUT DEVICE
65
INPUT DEVICE
66
SYSTEM BUS
54
TRANSMISSION LIGHT
DETECTION DEVICE
DETECTION CONTROLLER
67
CTL
61
MULTI-CH.
PHOTON-COUNTER
60
AMPLITUDE
DISCRIMINATOR
59
AMP
58
PMT
69
TEMP. CONTROLLER
68
FILTER
71
70
57
53
52
40
51
LIGHT SOURCE
CONTROL DEVICE
55
ACT1
ACT2
ACT3
ACT4
LD1
LD2
LD3
LD4
LIGHT SOURCE
L.S.
L.S.
L.S.
50-1
50-2
50-3
50-4
45 EXAMINATION
APPARATUS

FIG. 6


(a) DRIVING SIGNAL ACT1
(b) DRIVING SIGNAL ACT2
(c) DRIVING SIGNAL ACT3
(d) DRIVING SIGNAL ACT4
(e) CONTROL SIGNAL CTL
T0
φ11 φ12 φ13 φ14 φ15
CY1
φn1 φn2 φn3 φn4 φn5
CYn
φN1 φN2 φN3 φN4 φN5
CYN
Mk